Detecting volcanic glass in lunar localized dark mantle deposits

Erica Jawin[1]

Co-authors: S. Besse[2], L. Gaddis[3], J. Sunshine[4], J. Head[1], S. Mazrouei[5]

[1]Brown University, [2]ESTEC, [3]USGS, [4]University of Maryland, [5]University of Toronto

SSERVI ESF

NASA AMES Research Center, July 21-23, 2015

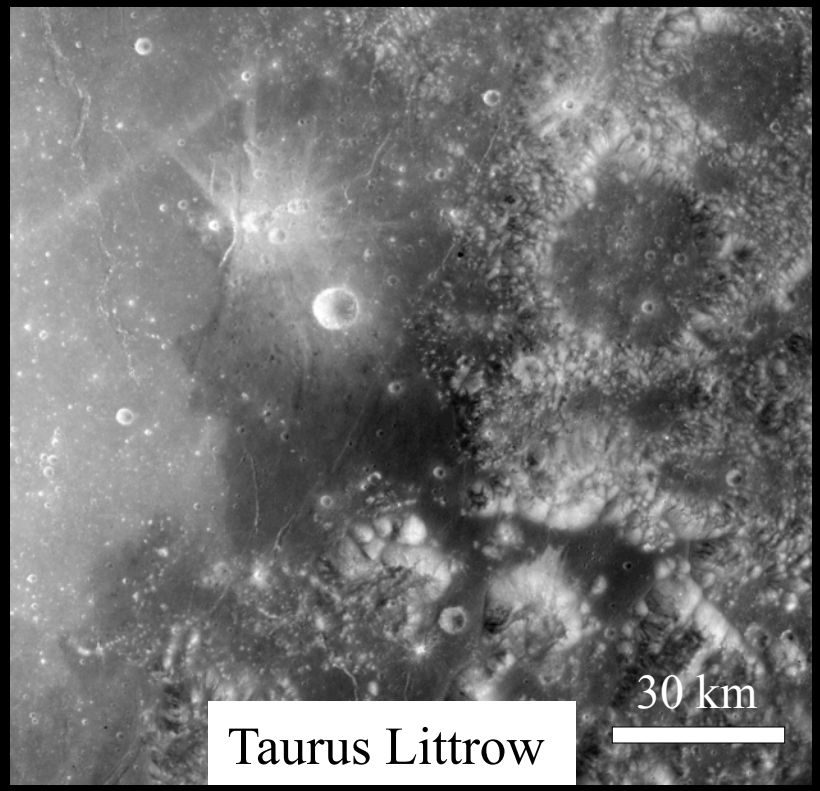
What are the spectral characteristics of lunar localized dark mantle deposits (DMDs)?

How much spectral variability exists within localized DMDs?

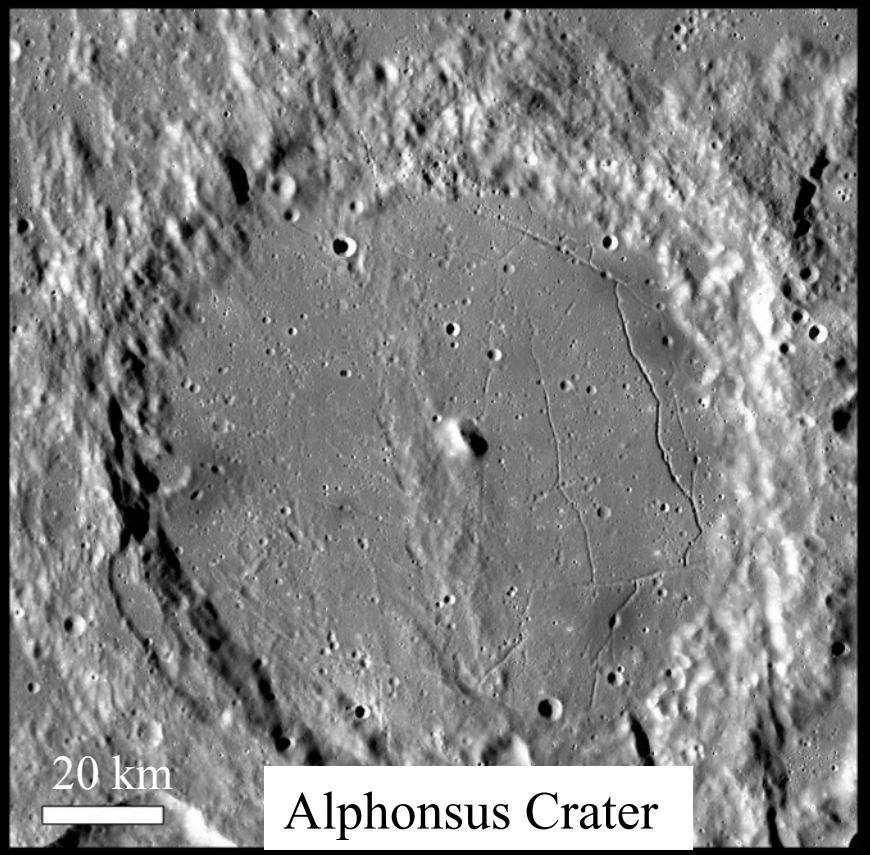
What are the eruption conditions of localized DMDs?

Dark Mantle Deposits

Large, Regional Deposits (>1000 km^2)



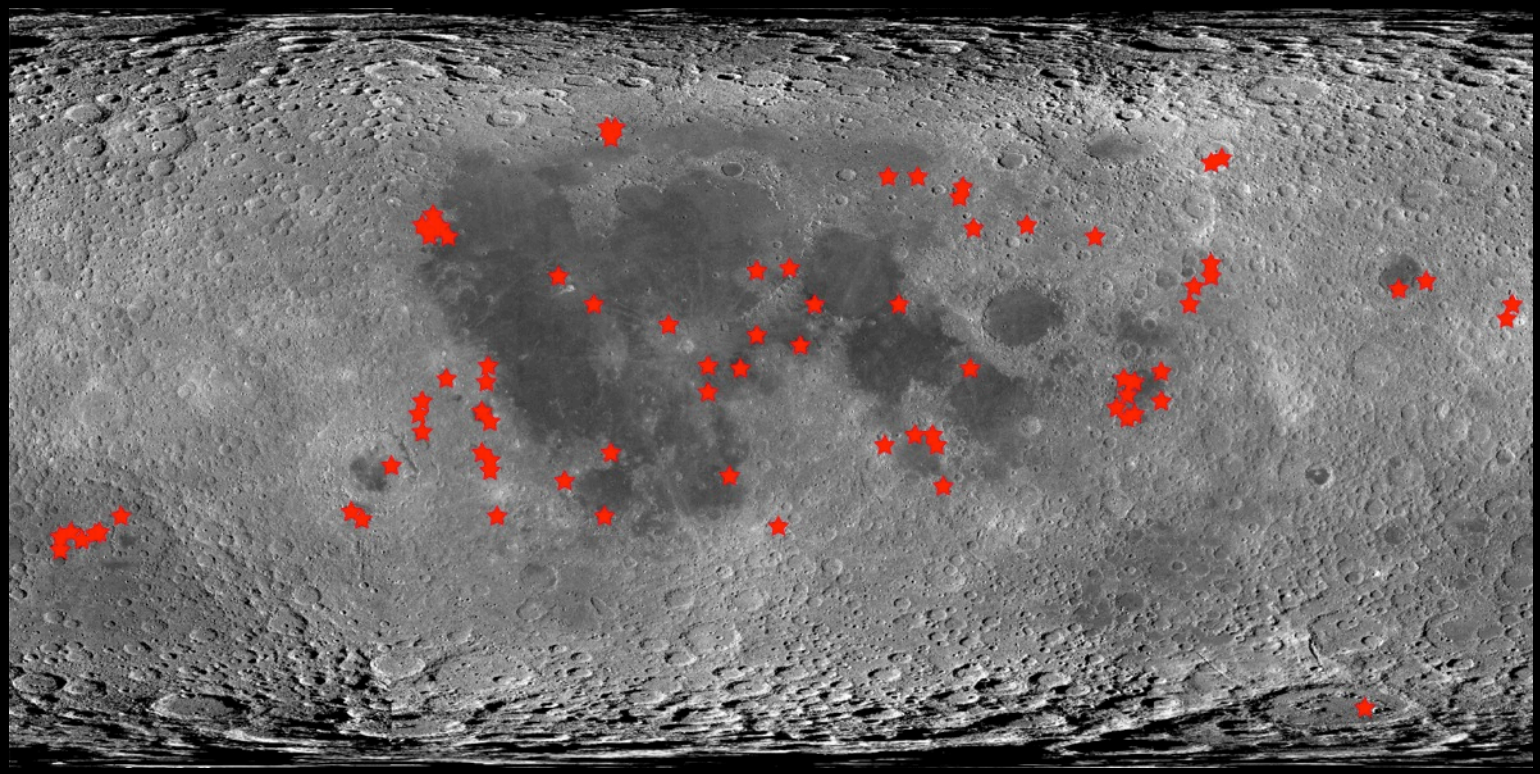
Small, Localized Deposits (<1000 km^2)



- Fine grained, low albedo
- Mantle topographic highs near basins, or in floor-fractured craters
- Stratigraphically old (relative to mare basalts)

[*Head,* 1974; *Gaddis et al.,* 1985; *Weitz et al.,* 1998]

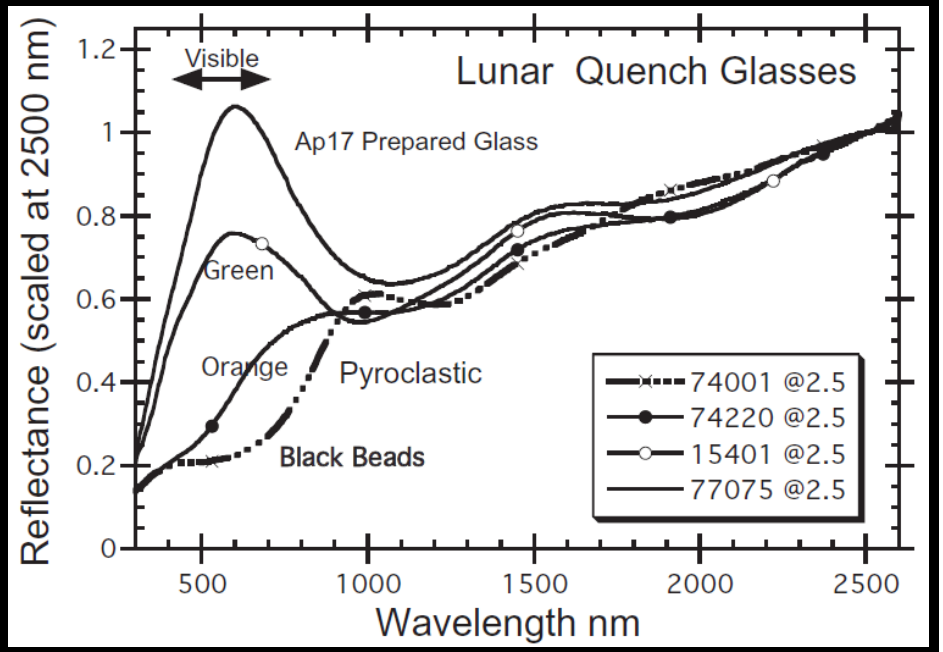
Dark Mantle Deposits: Distribution



Concentrated on the lunar nearside, associated with mare-filled basins or floor-fractured craters

[*Gaddis et al.*, 2003; *Gustafson et al.*, 2012]

Volcanic Glass



[*Tompkins &Pieters,* 2010]

Top: Ap17 Station 4
NASA image
AS17-137-20986HR

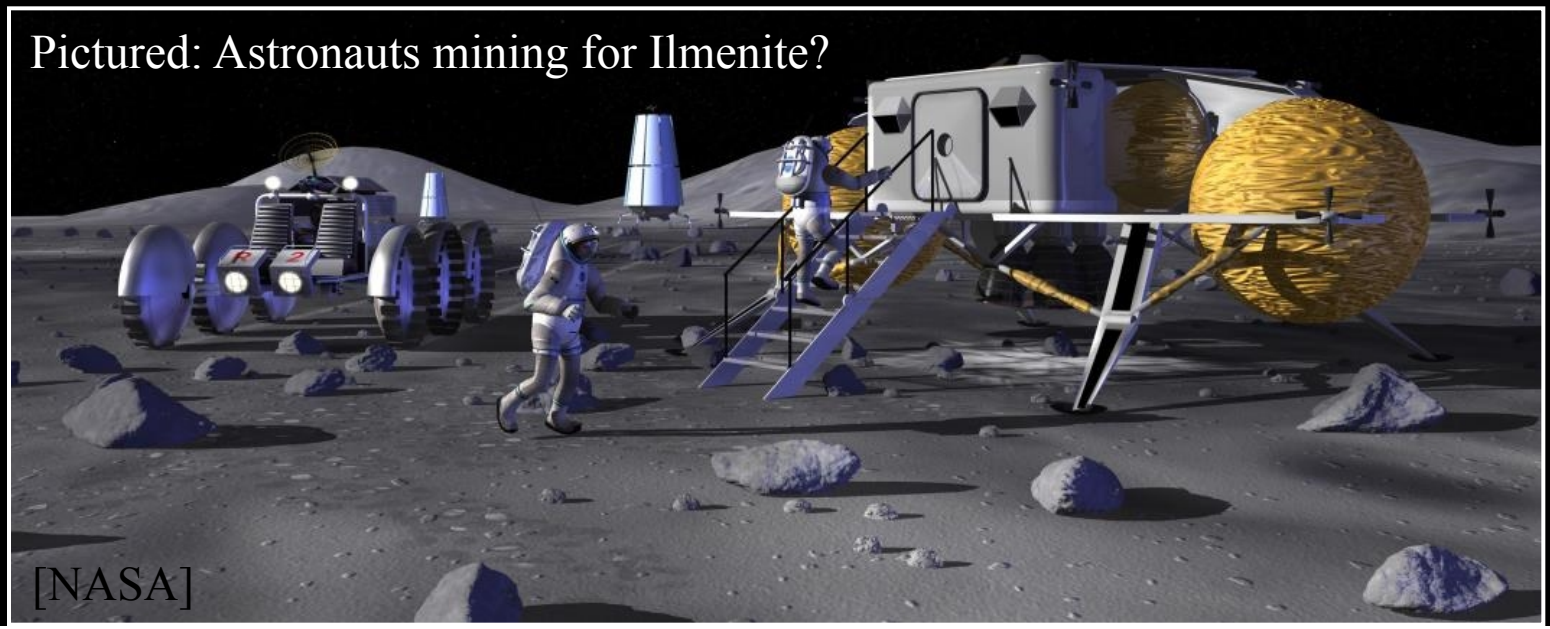
Bottom: Orange and black beads
Sample 74220
NASA image S73–15085

Quenched volcanic glass was returned from Taurus Littrow regional DMD, Apollo 17 landing site

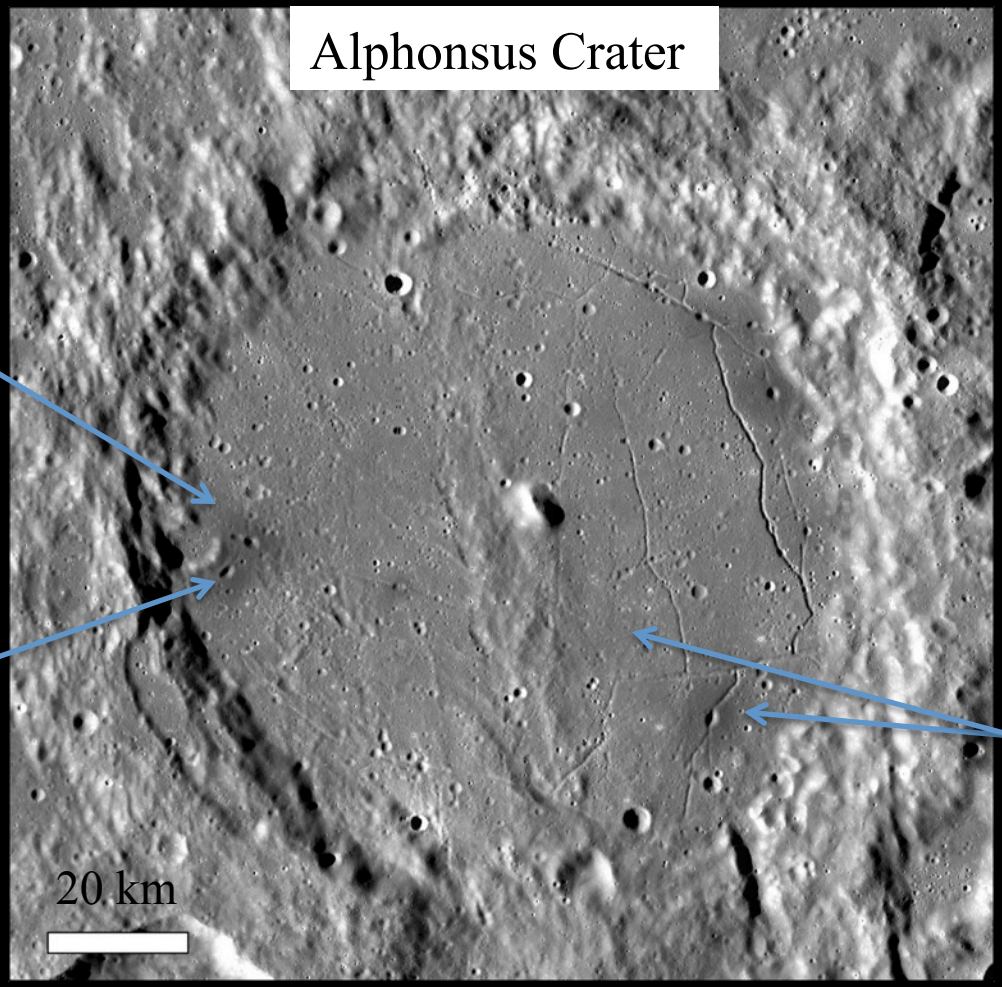
DMDs: Why do we care?

- Characteristic of volatile-rich volcanism
- Mafic mineralogical diversity
- Potential Lunar Outpost
- Resources
  - Ti, Fe, O, ^{3}He, solar wind-implanted volatiles,

[*Delano & Livi,* 1981; *Pieters et al.,* 1973; *Adams et al*., 1974; *Hawke et al., 1990; Duke et al., 2006*]



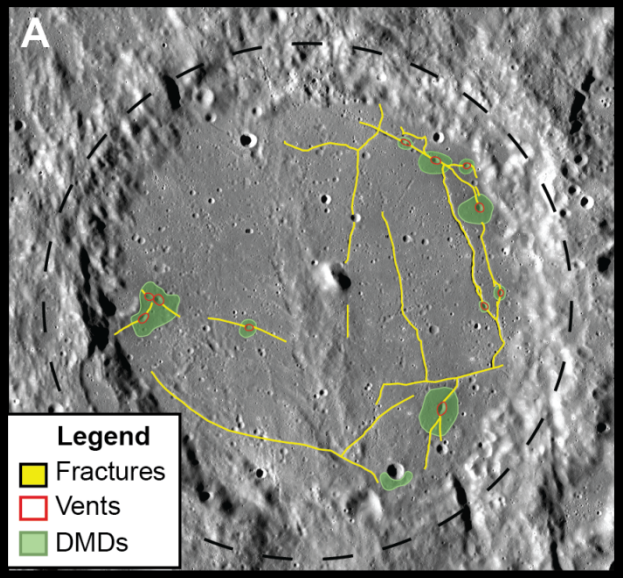
Localized Pyroclastic Deposits

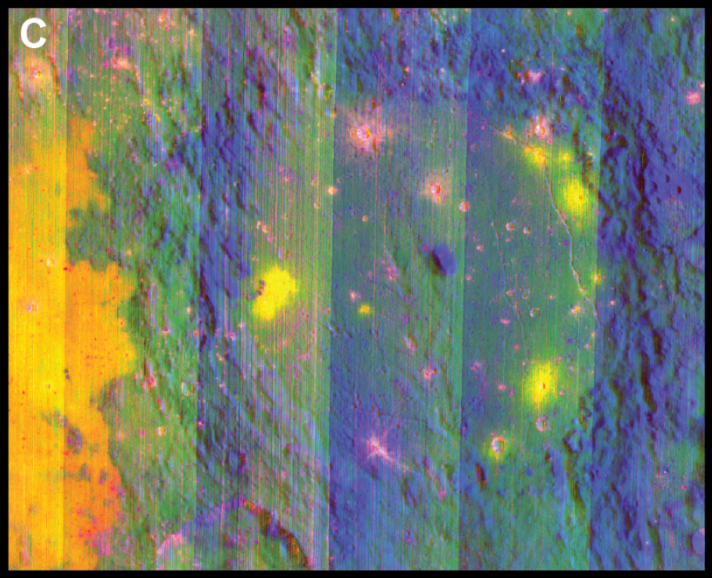


Analyzing spectra of localized pyroclastic deposits will aid in understanding mineralogy, variability, and eruptive conditions in small pyroclastic eruptions

Alphonsus Crater

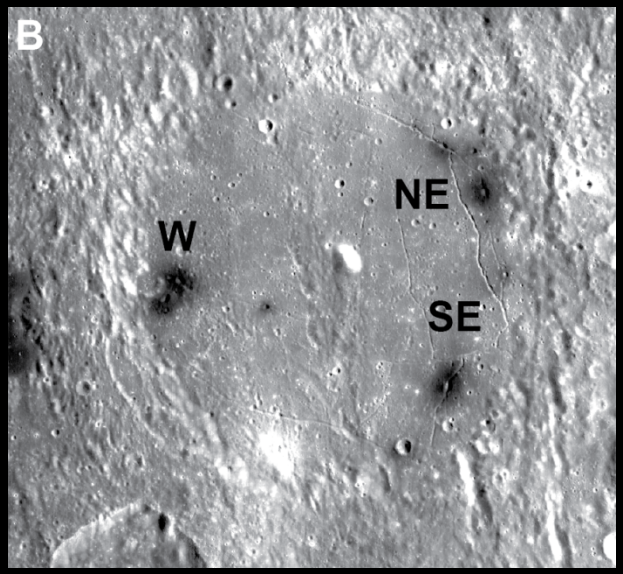
Kaguya TC evening mosaic

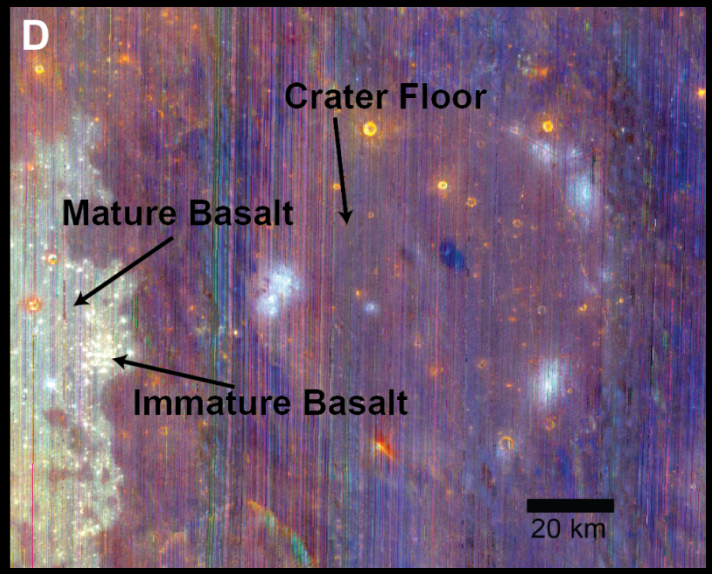




R: IBD 1000
G: BD 1900
B: R 1580

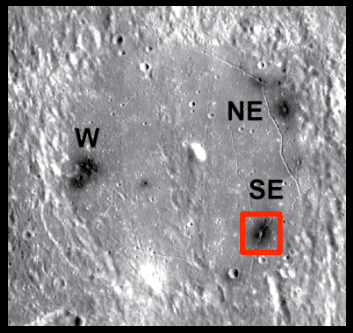
M^3 1000 nm albedo mosaic



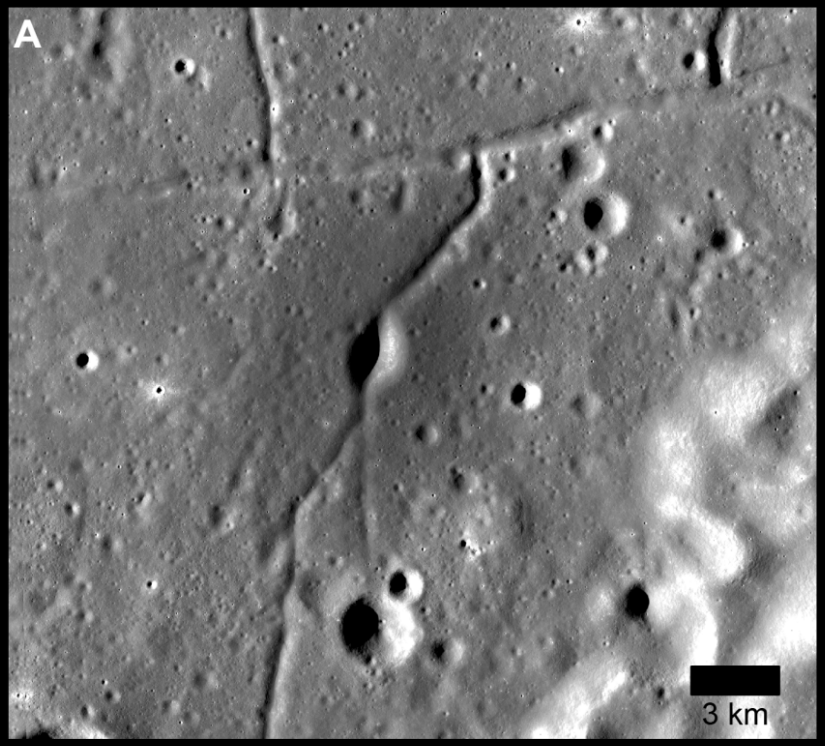


R: BD 950
G: BD 1050
B: BD 1250

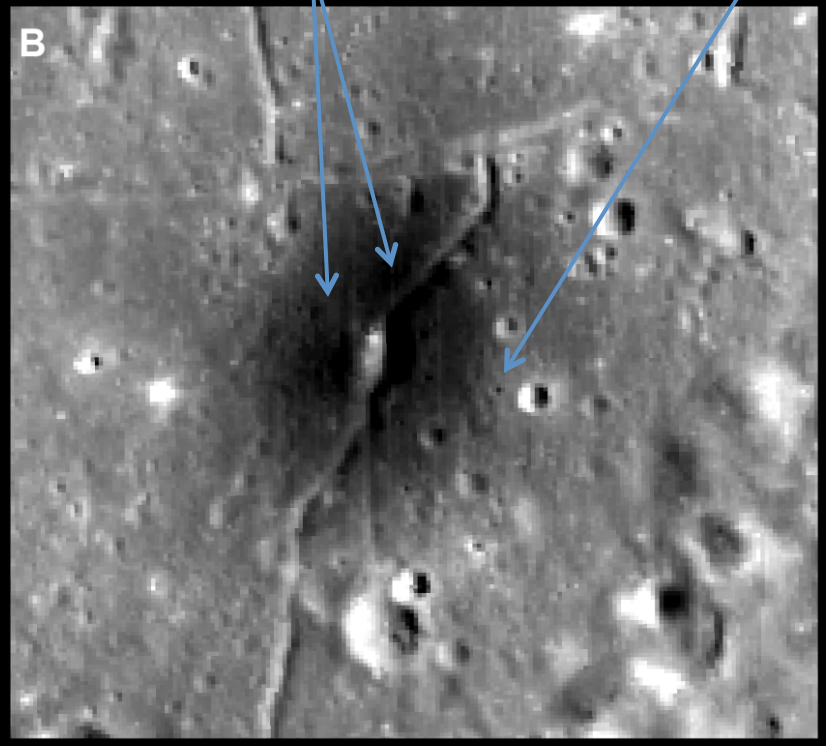
[*Jawin et al.,* in press]



Alphonsus SE Sub-deposit

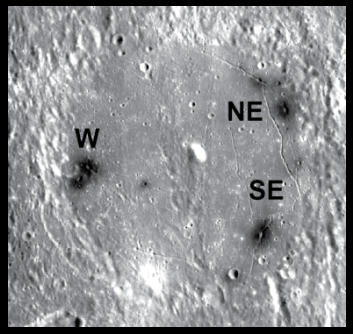


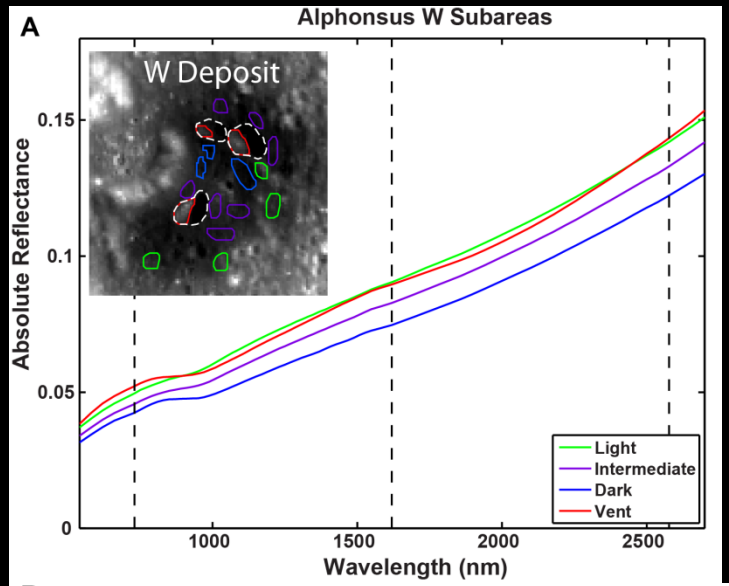
Kaguya TC Image



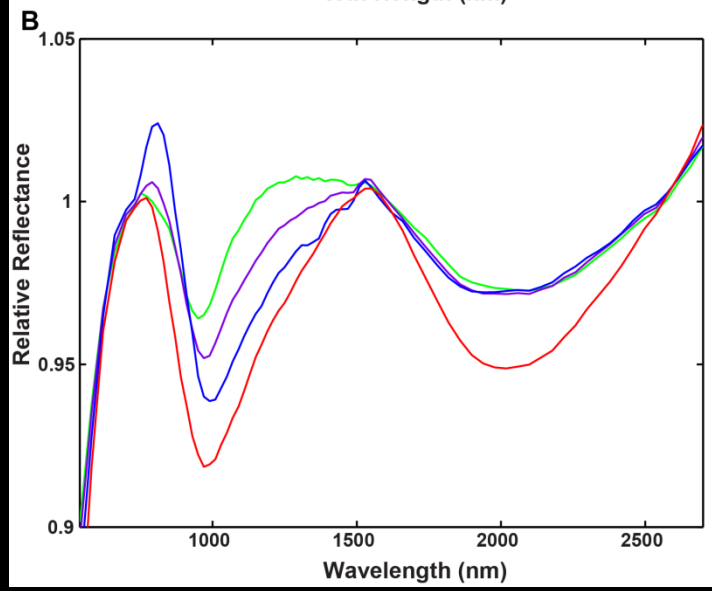
M^3 1000 nm Image

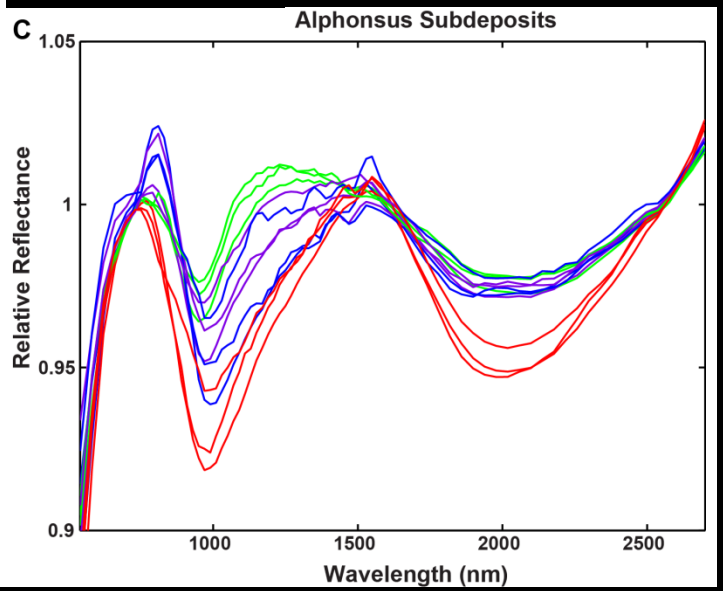
Alphonsus Spectra





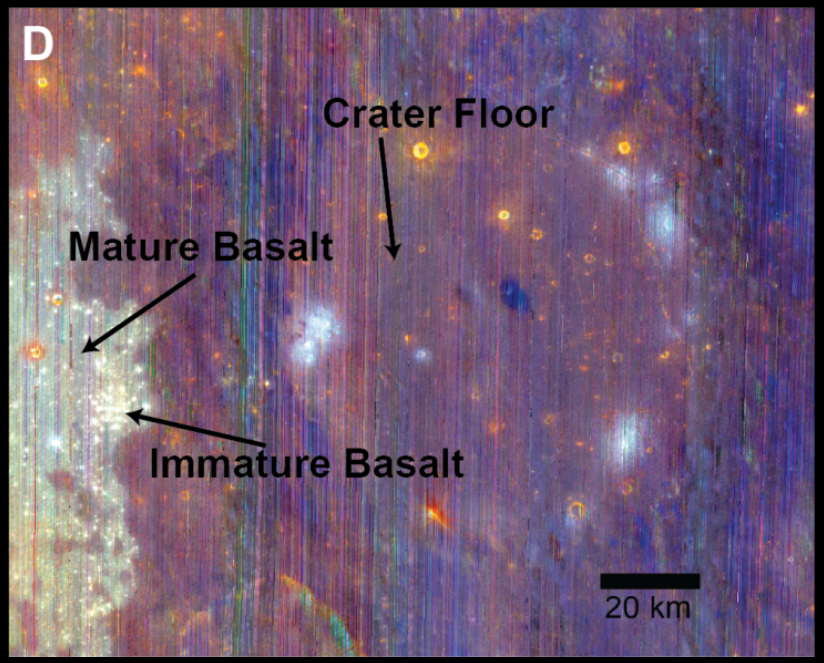
- Variable spectra
- Variation is consistent across sub-deposits
- Indicates mixing
- Glassy component present, enhanced near/inside vent

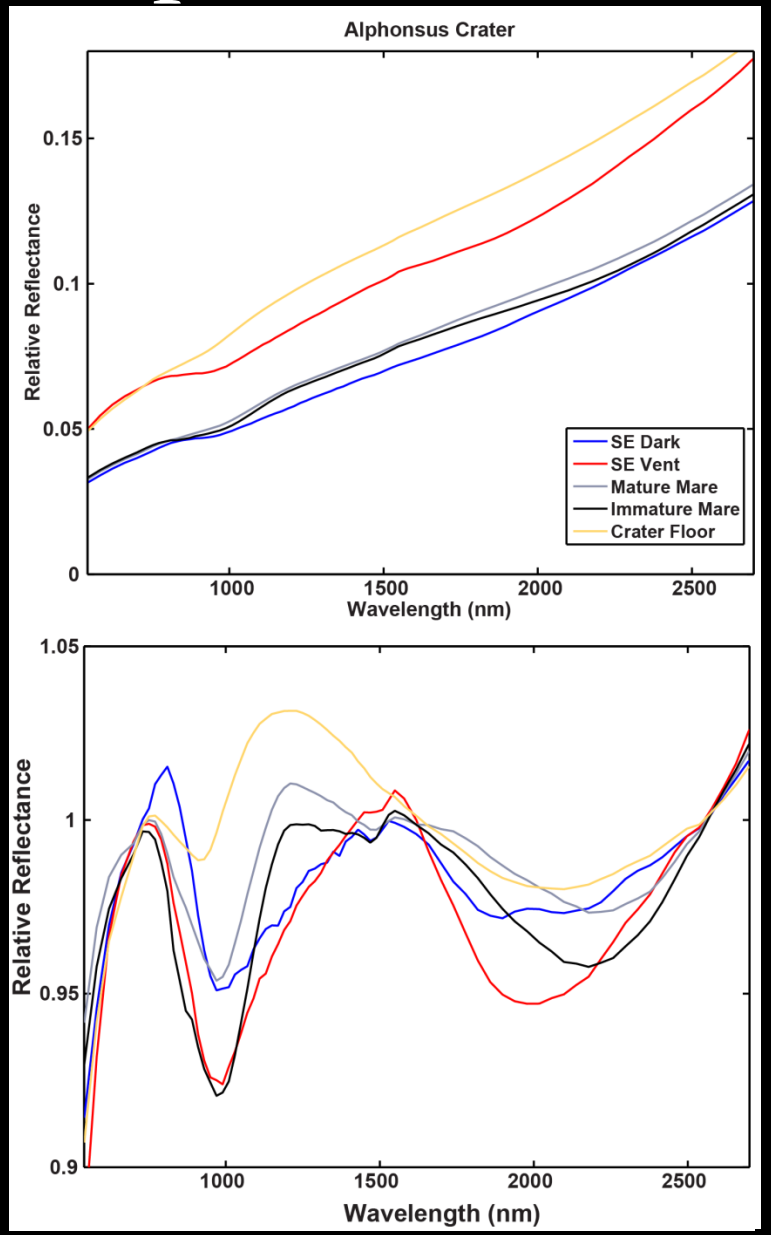




[*Jawin et al.*, in press]

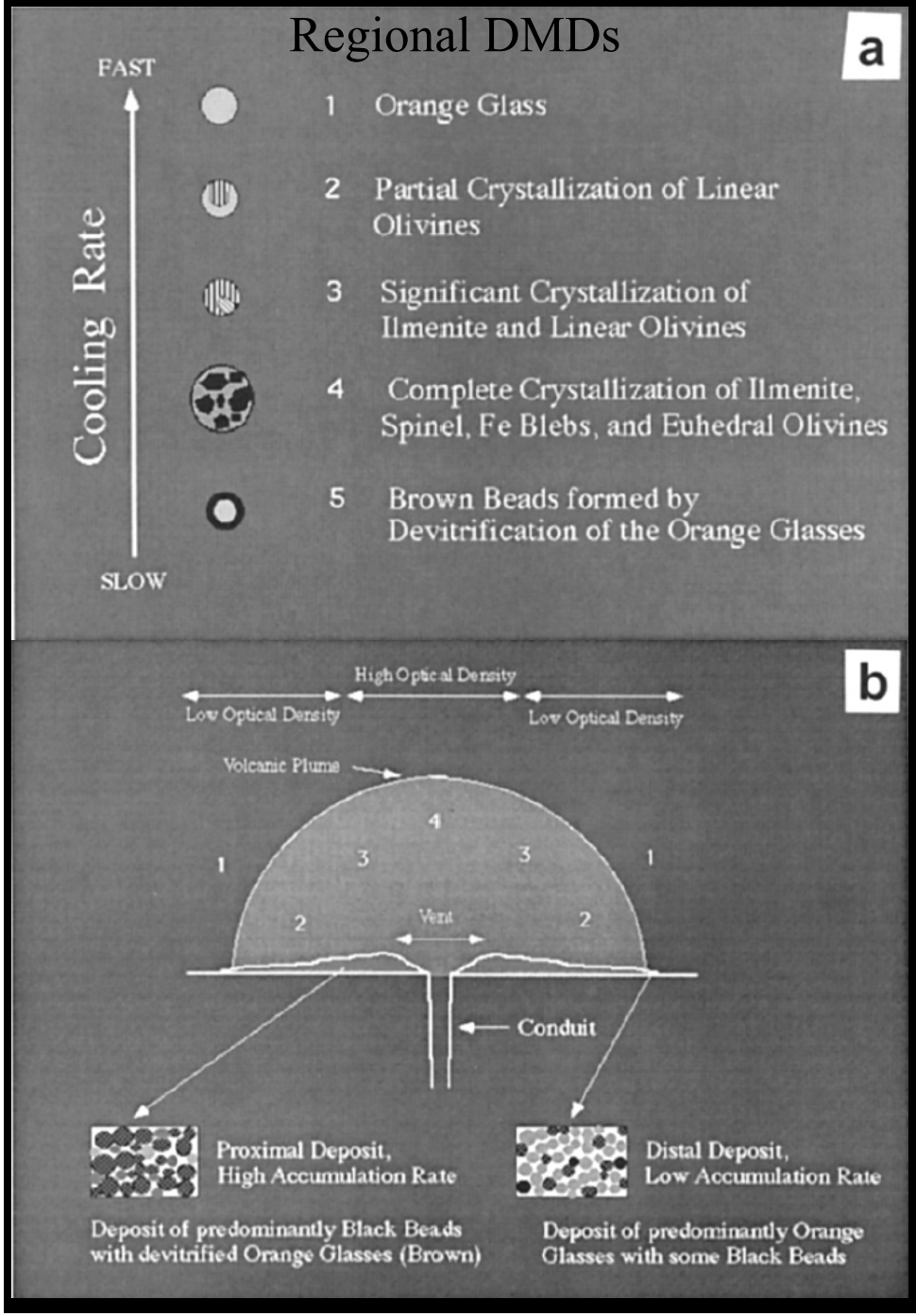
Alphonsus Spectra





- DMD spectra are unique from mare and crater floor
- Spectral distinction due to glassy component

[*Jawin et al.,* in press]

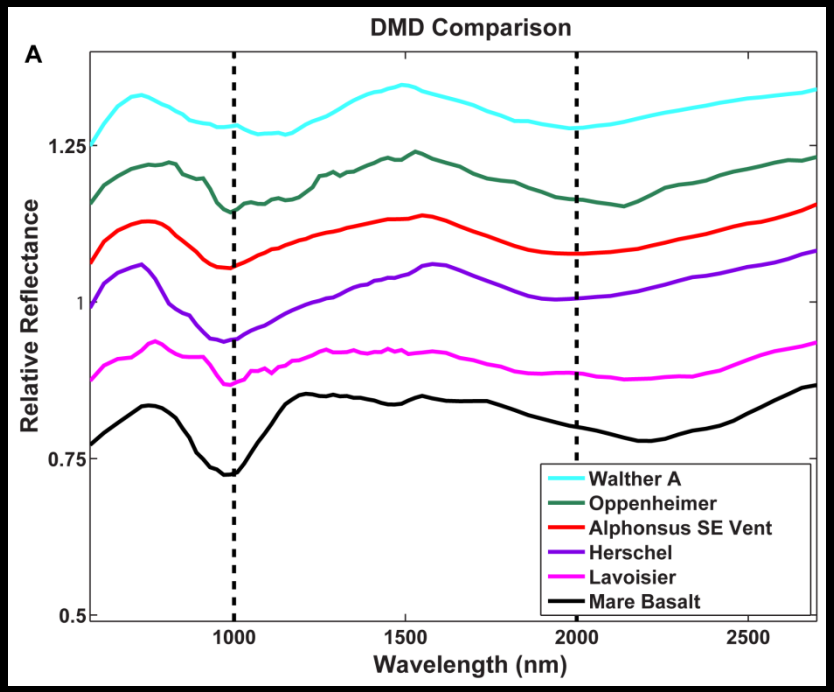


Implications of Volcanic Glass

- Strongest glass signature detected in, and close to, volcanic vent
- Optical density, temperature was low throughout emplacement
- And/or, multiple eruptions of decreasing magnitude

[*Weitz et al.*, 1999]

Other Localized DMD Glass Observations



[*Jawin et al.,* in press]

Localized DMDs containing spectral evidence of volcanic glass:

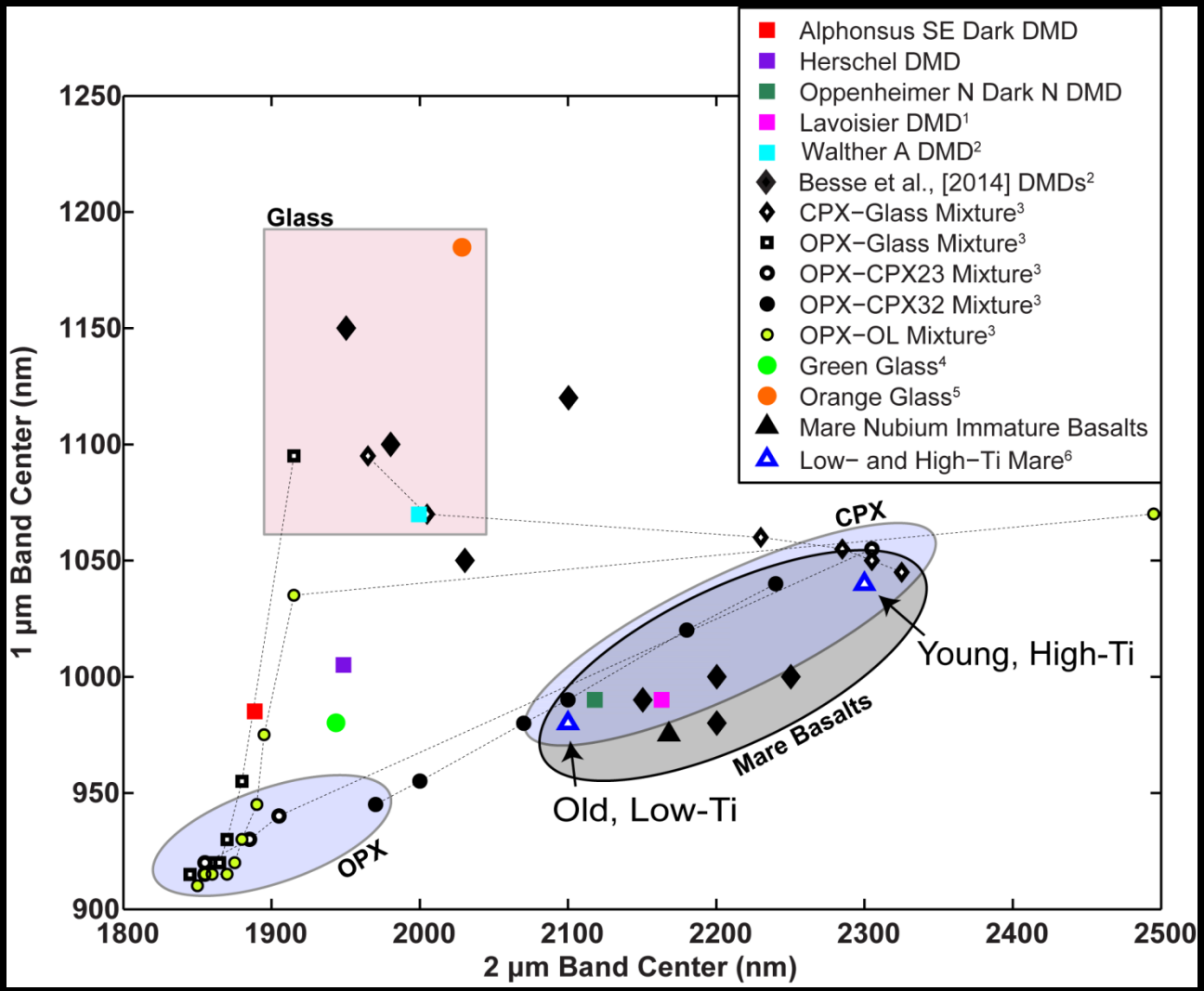
- Alphonsus, J. Herschel, Oppenheimer [*Jawin et al.,* in press]
- Walther A, Birt E [*Besse et al.,* 2014]

Evidence of glass-free localized DMDs

- Lavoisier [*Souchon et al.,* 2013]
- Andersons [*Besse et al.,* 2014]

Conclusions

- Alphonsus dark mantle deposits are characterized by mafic spectral signatures unique from nearby mare basalts that are variable, indicating mixing with the substrate
- Glassy signatures were identified in all sub-deposits in the DMD, interpreted to be quenched volcanic glass
- Glassy signatures were enhanced closer to the volcanic vent, suggesting higher glass concentrations in these locations
- In Alphonsus, eruptive conditions were similar across the crater
- Glass concentrations suggest an explosive, vulcanian eruption style
- Further analyses will place quantitative constraints on eruptive conditions



[*Jawin et al.*, in press]

Mineral Mixtures

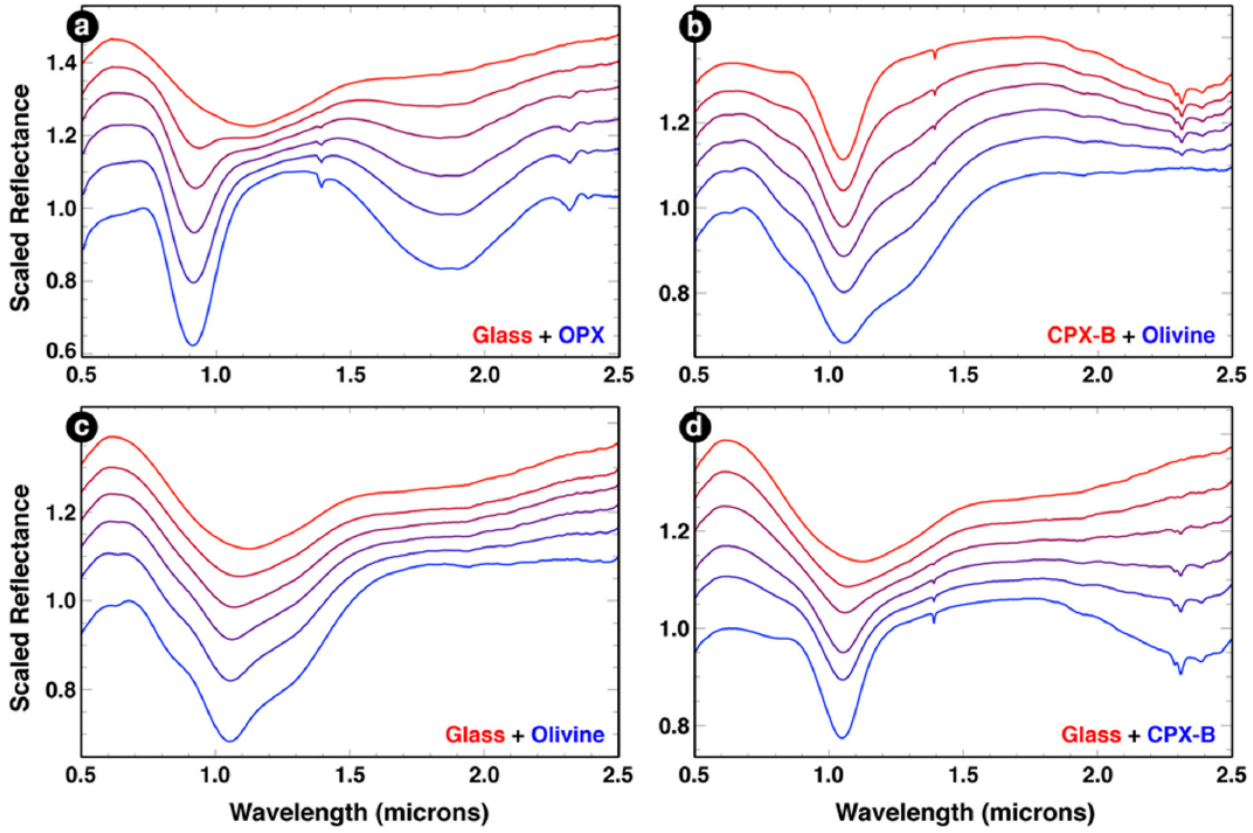


Fig. 4. Two component mixture spectra of Fe-bearing glass with pyroxenes and olivines, and CPX type-B with olivine. All spectra are derived from <45 μm grain size samples mixed at 20 wt.% intervals. (a) OPX (enstatite) and glass (tektite) mixture. (b) Olivine (forsterite) and CPX type-B (diopside) mixture. (c) Olivine (forsterite) and glass (tektite) mixture. (d) Glass (tektite) and CPX type-B (diopside) mixture. Spectra have been scaled and shifted for clarity. Narrow ~2.2 μm absorption bands present in some spectra are due to minor alteration. See Tables A4 and A5 for sample information.

[*Horgan et al.*, 2014]

Mineral Mixtures

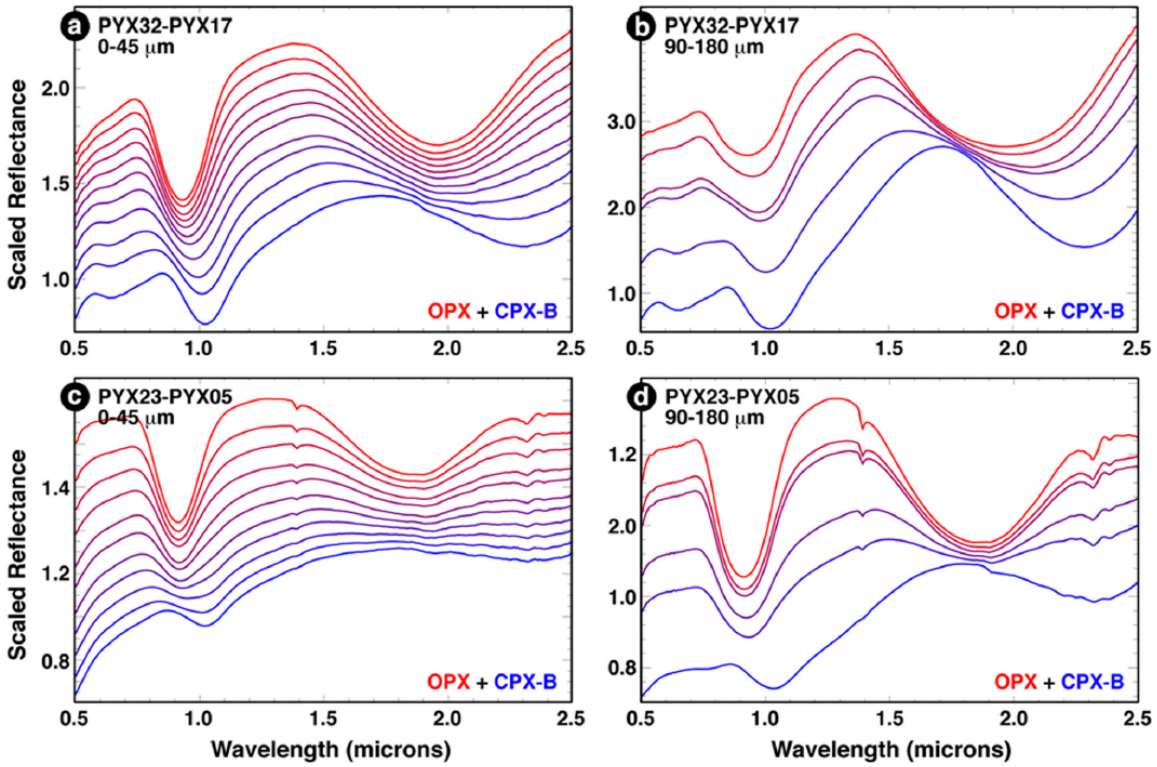


Fig. 5. Two component mixture spectra of OPX–CPX type-B mixtures for two different endmember sets: (a and b) hypersthene and endiopside, and (c and d) enstatite and diopside. Mixtures in (a) and (c) made at 0–45 μm and 10 wt.% intervals; (b) and (d) at 90–180 μm and 20 wt.% intervals. Note that while the hypersthene/endiposide mixture linearly transitions between the two endmembers, the enstatite/diopside mixture does not. The enstatite dominates the spectrum much like in mixtures of OPX with olivine or glass (Figs. 4 and 6), in all cases due to the greater absorption strength of the OPX relative to the other endmembers. Narrow ~1.4 and 2.2 μm absorption bands present in some spectra are due to minor alteration. See Tables A4 and A5 for sample information.

[*Horgan et al.*, 2014]

Mineral Mixtures

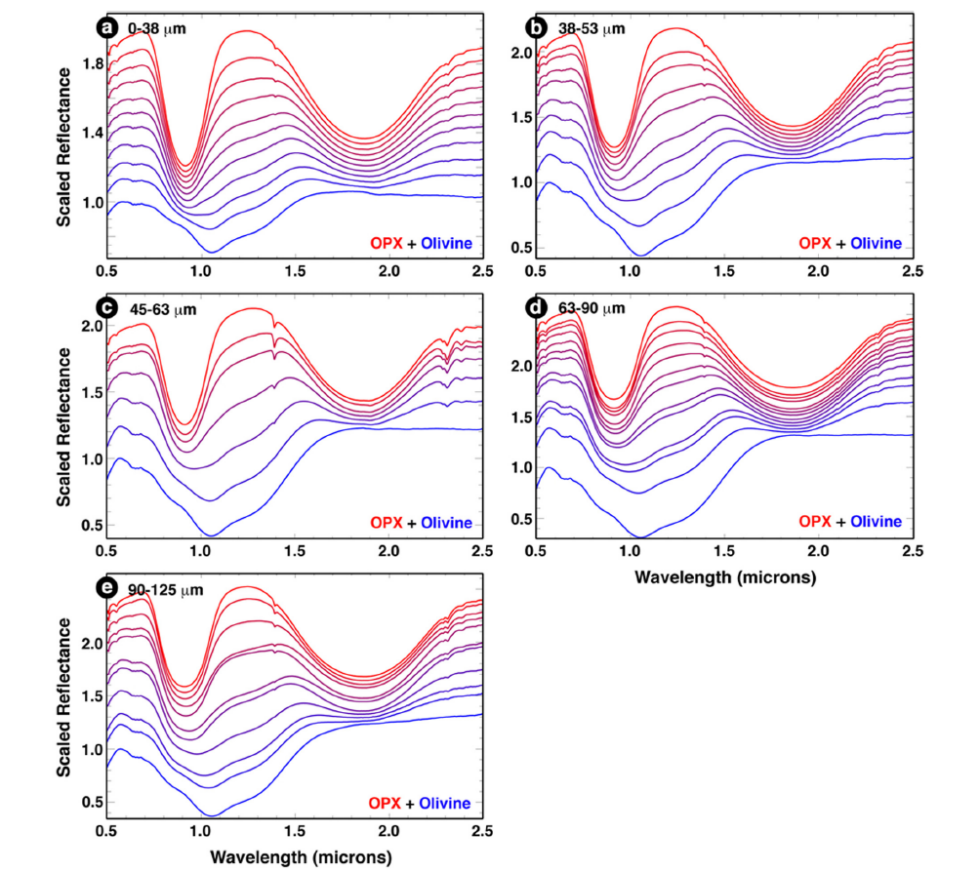


Fig. 6. Two component mixture spectra of OPX (enstatite) and olivine (forsterite) mixtures at varying grain sizes, and 10 wt.% intervals unless otherwise noted: (a) 0–38 μm grain size samples, (b) 38–53 μm, with no 50/50 spectrum, (c) 45–63 μm at 25 wt.% intervals with additional spectra at 10 and 90 wt.% OPX, (d) 63–90 μm with additional spectra at 85 and 95 wt.% OPX, and (e) 90–125 μm. Narrow ~1.4/2.2 μm absorptions present in some spectra are due to minor alteration. See Tables A4 and A5 for sample information.

[*Horgan et al.*, 2014]